

ART. V.—THE TENDON-REFLEX: ITS PREVALENCE AND ITS PHYSIOLOGY.

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IN 1874 Professors Erb and Westphal each published in the same number of the same journal* a paper on what has come to be known in English as the "tendon-reflex," frankly sharing the honors of priority with each other, and thus presenting an example of magnanimity too rarely emulated by professional men. They were the first to bring into notice the fact that when the tendon of the quadriceps extensor muscle of the leg was lightly and quickly struck below the knee, there immediately followed a jerk forward of the foot and leg. As it is almost superfluous to remark by way of reminder, they attached great value to this phenomenon as a symptom of disease, since Westphal claimed that its absence was pathognomonic of locomotor ataxia, while Erb asserted that its presence in an exaggerated degree was constant in spasmodic spinal paralysis. The literature of the subject from that period to the present date would fill several portly folios. Schultze and Fürbringer,† Berger,‡ Henze,§ Sachs,§ Burckhardt,¶ Lewinski,** Westphal again,†† Tschirjew,‡‡ Muhr,|| Gowers,§§ Sawyer,¶¶ Hamilton,*** Bannister†††; all have

* *Arch. f. Psych.*, 1874. S. 792, 803.

† *Centralbl. f. d. med. Wissensch.*, 1875, No. 54.

‡ *Sitzb. d. Schles. Gesellsch. f. vaterländ. Cultur.*—Med. Sect., 23 Juli, 1875.

§ *St. Petersb. med. Wochenschr.*, 30 October, 1876.

§ "Die Nerven der Sehnen," *Reichert u. DuBois-Reymond's Arch.*, 1875. S. 402.

¶ *Festschr. d. Andenken an A. v. Haller*, Bern, 1877.

** *Arch. f. Psych.*, VII. S. 327, 1877.

†† *Ibid.*, VIII. Hft. 2, and *Berl. klin. Wochenschr.*, No. 1, 1878.

‡‡ *Arch. f. Psych.*, VIII. Hft. 3.

|| *Psych. Centrbl.*, No. 2, 1878.

§§ *Brit. Med. Journ.*, Aug. 31, 1878.

¶¶ *Ibid.*

*** *Bost. Med. and Surg. Journ.*, Dec. 19, 1878.

††† This journal, October, 1878.

contributed, in varying degree, to the question. It cannot be gainsaid that the clinical importance of the phenomenon has been eagerly appreciated in this country and abroad; and whatever tends to its elucidation, be it ever so slight, or to a more exact comprehension of its practical applicability, as well as of its relations to the recognized mechanisms of the cerebro-spinal axis, should not only possess an intrinsic interest but also an adventitious one lent to it by the present current of neurological thought.

It has seemed to me that the significance of the tendon-reflex in disease is so largely dependent upon exact knowledge of its modes of existence in health as to warrant an investigation into the latter. I have, therefore, endeavored to obtain some guiding facts in regard to its normal prevalence in the adult and the child, its usual site, the variations in the degree of its manifestation, its relative strength upon the two sides. In the course of this inquiry, I have, for the sake of uniformity, observed certain invariable rules. I have always made use of the tendinous expansion below the patella of the quadriceps extensor muscle. I have always taken care that the thigh should be supported by my arm placed in the bend of the knee, the leg dangling passively. I have always tapped upon the bare skin; and, finally, I have selected subjects about whose health, past and present, there could be no suspicion.

Prof. Westphal makes the positive statement in his latest article that he has yet to find a person in whom the tendon-reflex of the quadriceps is normally absent; this, too, in spite of observation of a large number of healthy individuals. I regret that my experience does not coincide with his. Among thirty adults I have encountered two in whom this phenomenon could not be evoked in any manner whatsoever, or in any place, either by a light tap or a stout blow, either above or below the patella, either at one time or at another. Among twenty-three children it has been my fortune to meet with one, in whose one leg it was not to be gotten, and in whose other leg it was very weak. Bannister* failed to find it twice among about thirty-six healthy individuals, mostly adults.

*Op. cit.

In the great majority of adults I have ascertained that the tendon-reflex could only be produced by tapping about one inch below the lower edge of the patella, either at or slightly to one side of the median line; whilst in a small number the characteristic forward jerk would follow a blow upon the tendon at any point over a larger surface, this surface sometimes extending from the patella to two inches below. The most usual site in children—fifteen out of twenty-three—whence alone the tendon-reflex can be evoked, is on the lower edge of the patella; in a lesser number it is confined to a spot just below this, or it is slightly diffused. The variations in the strength of the manifestation were wide, being in some cases, as I have said, absolutely nil, in others weak, in still others violent; indeed, the normal limits touch, upon the one hand, the pathological absence of locomotor ataxia, while, upon the other, they attain to the pathological exaltation witnessed in the moderate cases of spasmodic spinal paralysis.

In somewhat over one-half of the subjects—eighteen out of thirty-two—the tendon-reflex was not of equal strength upon the two sides. The difference was slight in one-half the cases, strongly marked in the other moiety. There was apparently no constant preponderance of strength or weakness upon either side.

The fact seems to have been overlooked that the tendon-reflex of the quadriceps extensor, whatever be its value, can only be of use in a disease involving the lower extremities, and only indirectly, if at all, of service in affections of the upper limbs. The triceps is to the humerus and the ulna what the quadriceps extensor is to the femur and the tibia—the great extensor muscle of the limb; so forcibly, indeed, did the analogy impress the mind of Cruveilhier that he described the latter by the name of the triceps femoralis. It has occurred to me, therefore, that the triceps, being the analogue of the quadriceps, might be utilized for diagnostic purposes in the upper limb, as the other has been used in the lower. Like its analogue, it terminates in a large flat tendon, superposed upon a bony base, and thus favorably shaped and situated for the manifestation of the phenomenon of which I am treating. In eighteen subjects whom I have examined, I

have found the tendon-reflex of this muscle always present. It is not, however, so easily evoked as in the quadriceps, a smart, quick blow with a percussion-hammer being necessary to its production. The strength of the manifestation has been moderate, varying but slightly, and far less than in its fellow of the leg. In examining this muscle, I have supported the arm of the subject at a right angle to the trunk by my hand placed in the hollow of his elbow, taking care that the forearm hangs passively; and I have always tapped upon the bare skin.

The physiology of the tendon-reflex has been a much-mooted problem. I have endeavored to determine for myself whether it is really a reflex action, or whether it is due to an inherent muscular irritability. For this purpose I have made a number of experiments upon rabbits. In these animals the tendon-reflex of the quadriceps extensor is easily obtained. I have always laid them upon the back; then flexing the leg upon the thigh, in which position the animal will generally permit it to remain, and grasping the thigh with the one hand, I have lightly tapped with the other by means of a percussion-hammer upon the quadriceps tendon as it is stretched across the anterior surface of the knee like a narrow drum-membrane; at the same time I have been particular to discriminate between the resulting quick, sharp, jerky jerk of the foot, and the heavy, inert movement of the leg and foot as a whole that may be produced in the delicate limbs of the rabbit simply by the shock of a blow, without any muscular action whatever. Ascertaining in each individual animal the presence of the tendon-reflex, I have broken up the spinal cord between the different lumbar vertebræ, and observed the effect. *I have satisfied myself that destruction of the cord between the fifth and sixth lumbar vertebræ instantly causes the tendon-reflex of the quadriceps extensor to cease.* Strike now as strongly as you will upon the tendon, there is absolutely none of that sudden movement of the foot which was so marked a few moments before. An animal upon whom this operation had been performed was kept alive for three days, but there was not witnessed any return of the phenomenon. Sections of the cord between the other vertebræ

increased the tendon-reflex of the quadriceps, simultaneously with the other reflexes. These experiments are repetitions of those made by Tschirjew,* and confirmatory of them. Schultze and Fürbringer† had previously demonstrated that section of the crural nerve also put an end to the tendon-reflex of the quadriceps.

The tendon-reflex of the quadriceps extensor is therefore truly a reflex. In other words, for its manifestation it is necessary that there should be a structural integrity: *a.* of a certain portion of the spinal cord, probably of its grey matter, what is called in the fashionable phraseology of modern science, a *centre*; *b.* of certain nerve fibres conducting impressions inward to the cord, *afferent* nerves; *c.* of certain nerve fibres conducting actions outward from the cord, *efferent* nerves. What is true of one muscle is probably true of all. What is true of the muscles of rabbits is probably true of similar phenomena in human muscles. As the crural nerve in the rabbit takes its origin, according to Krause, in the spinal cord between the fifth and sixth lumbar vertebræ, as it is distributed to the quadriceps extensor, and as section of it and of this segment of the cord destroys the tendon-reflex, it follows that the afferent and efferent nerves of the tendon-reflex of this muscle run within the sheath of the crural nerve. Are they, then, the ordinary motor and sensory nerves, linked by the centre common to such nerves? After some experimentation and thought, I am prepared to meet this question with a decided negative. I am prepared to state my belief that the nervous apparatus of the tendon-reflex—its spinal centre, its afferent and its efferent nerves—are entirely distinct from the nervous mechanism of the ordinary motor and sensory nerves.

My reasons for this belief are as follows:

1.—*The nerves possess a different excitability from that of the ordinary motor and sensory nerves, and are animated and depressed by different stimuli.*—I have repeatedly administered ether to rabbits to such an extent as to have the limbs become perfectly flaccid, at the same time that the deep thrust of a knife-blade produced not the slightest movement—in brief, to

* Op. cit.

† Op. cit.

such an extent as to have absolute motor and sensory paralysis—whilst the tendon-reflex of the quadriceps was undiminished, or even increased in strength. I have repeatedly obtained similar results with chloroform. Westphal and Erb have completely paralyzed the motor nerves of animals by means of woorara without injury to the tendon-reflex. All the German observers concur in stating that it cannot be evoked in any other manner than by tapping upon the tendon. Heat, cold, chemical irritants, electricity—unless a strong current be applied—fail to call it forth. I have observed one striking fact, germane to this particular, in all my experiments: When the spinal cord with its membranes is laid bare, there ensues a short period of extreme shock in the animal, during which there is complete loss of motion and sensation, even though no anæsthetic have been employed; it is, indeed, precisely at this period of painlessness that Claude Bernard advises the physiologist about to operate upon the nerve roots to isolate the posterior one, rather than wait until its sensibility is restored and the movements of the animal offer serious hindrance. But at this period the tendon-reflex, far from being abolished, is actually increased in strength! Tschirjew* exposed the crural nerve, encircled it with a light string, gently raised it upon the string, and thereby abolished the tendon-reflex of the quadriceps. There was, however, no symptom of any interference with ordinary motility or sensation, so far as could be inferred from the facts that the muscle was not appreciably relaxed and that the sensibility of the exposed nerve had not been altered. Its absence or its increase in the healthy, moreover, is not attended by any appreciable derangement of the ordinary nerves. Pathological facts, scanty as they are, are not at variance with the physiological. Whether the tendon-reflex be universally absent or not in *locomotor ataxia*, it is certain that it is wanting in a certain proportion of cases, and at a stage long anterior to the onset of any paralytic phenomena. On the other hand, it is greatly increased in spasmodic spinal paralysis, a disease which is not, as a rule, accompanied by any hyperæsthesia, and in

* Op. cit.

which there is not infrequently a slight anæsthesia. Muhr* affirms also that it is generally present in general paresis.

2. *These nerves are either not at all or imperfectly under the control of the will.*—Tap at the proper point upon the quadriceps tendon of a strong man, and he will be unable to prevent the immediate forward jerk of the foot. I have had an opportunity of testing this particular in an exceptionally favorable individual. There is a certain Mr. Mann, well known of late to the profession of New York and other cities, who possesses a remarkable and probably unprecedented control over the different muscles of his body and extremities. He can at will produce dislocations of the various joints by snapping the articulating surfaces of bones out of their sockets. He can so contract and expand his chest that the difference between the maximum expansion and the maximum contraction is thirteen inches. He can so contract his abdominal muscles as almost to lay the recti against the vertebral column. He can exactly simulate a talipes varus. But he cannot prevent the peculiar jerk of the foot, when I tap upon his quadriceps tendon. He can limit it by a simultaneous and violent action of the muscles of the calf of the leg; stop it, he cannot.

3. *It is probable that these nerves possess a much slighter sensibility than the ordinary sensory nerves.*—When the tendon-reflex is evoked in the human being by tapping upon the quadriceps, the blow which is adequate to produce what is oftentimes a violent muscular movement gives rise either to no sensation at all, or to a very faint one. Under no circumstances that have come under my observation, in the healthy or in the sick, is the blow felt as it would be if impinging upon an ordinarily sensitive nerve, as upon the ulnar at the elbow for instance.

4. *These nerves do not possess the same conductivity as do the ordinary motor and sensory nerves.*—Burckhardt† and Tschirjew‡ are at some variance with each other in regard to the actual rate of transmission of the nervous current in these

*Op. cit.

†Op. cit.

‡Op. cit.

fibres, but they both agree in stating that the length of time intervening between a blow upon the quadriceps tendon and the ensuing jerk of the foot is greater than would be ordinarily consumed by the passage of a nervous impulse inward along a sensory nerve to the spinal cord, through the spinal ganglia, and outward along a motor nerve to the quadriceps. The explanations offered by these writers are very unsatisfactory and contradictory. Burckhardt makes the singular and incomprehensible suggestion that the time employed is sufficient for the passage of the nervous impulse through the lumbar plexus or the spinal ganglia, or for the direct irritation of the muscle. Tschirjew inclines to the belief that the intraspinal paths of conduction of these nerves must be shorter than usual, or must be endowed with an unwontedly rapid conductivity. If my foregoing argument have any value, its statements should conduct us to the simple and satisfactory conclusion that these nerves possess a conductivity of their own, differing greatly from that of the ordinary motor and sensory nerves. In all my experiments I have been impressed with a fact that lends support to this view. A blow upon the quadriceps of one leg of a rabbit, be the tap ever so light, will not only evoke the tendon-reflex of the corresponding side, but will also bring forth in lesser degree that of the opposite knee, without causing any other muscular movement.

To sum up, then, it appears that these nerves differ distinctly from the voluntary motor and sensory nerve fibres in being affected in a different manner by the same influences, in being affected by other influences, in being but slightly under the control of the will, in being but slightly sensitive, in possessing a much more rapid conductivity. I have no doubt but that they are distinct nerves; and I would suggest for them the name of *tendon-nerve fibres, motor and sensory*.

It would seem evident from the preceding facts that the tendon-nerve fibres belong to the class of the involuntary nerves. This opinion is strengthened by further inquiry. Contrary to the experience of Erb and Westphal, I have succeeded in abolishing the tendon-reflex in rabbits by means of ether, chloroform and woorara. This I have done with ether and chloroform by pushing the anæsthetization until there were

distinct symptoms of approaching paralysis of the involuntary nerve nuclei of the medulla oblongata, as evidenced in the most of my animals by the characteristic cry, entirely similar to the one which may be produced by touching a certain portion of the medulla with a stylet, or by a marked diminution and deliberation of respiration, as well as by extreme rapidity of the heart-beat. When this degree of narcosis is reached, and invariably when heralded by the peculiar involuntary cry, the tendon-reflex of the quadriceps has ceased. Removing the anæsthetic and allowing the animal to slowly revive, the tendon-reflex has remained absent for a period varying from a minute to a minute and a half, and has then suddenly returned in increased strength. At the period of this return, the respiration increases in frequency, to and beyond the normal, the while the cardiac pulsations are reduced in frequency; in a word, the return of function in the nerves of the tendon-reflex comes *pari passu* with the return of function in the pneumogastric. Chloroform produces this cycle of events more rapidly than does ether, and it also abolishes the tendon-reflex for a slightly longer time. When use is made of woorara, the tendon-reflex disappears at the moment of great diminution or cessation of respiration, and of tumultuous action of the heart; but whether it reappears or not I am unable to say, as my experiments with this drug have been fatal to the animals. It will be remembered that the tendon-reflex was exalted at the moment of opening the spinal canal and exposing the cord and its membranes to the air. Precisely at this moment, also, the respiration increases greatly in frequency and the cardiac pulsations decrease; that is to say, the functional activity of the par vagum is greatly increased. The increase of this peculiar reflex in spasmodic spinal paralysis is, furthermore, though not attended with any exaggeration of reflex action in the voluntary nerves, frequently synchronous with an increase of function in the involuntary nerves of the bladder, giving rise to the frequent micturition of this malady. These details, when considered together with the imperfect response to volition, the slight degree of sensitiveness, certainly seem to show a close relationship between the tendon-nerves and the class to which the pneumogastric belongs.

But, it may be reasonably asked, is there any proof that an involuntary nerve like the pneumogastric ever terminates in a voluntary muscle like the quadriceps? Certain experiments of Claude Bernard,* the peerless reporter of nature, are very significant in this regard; and it is difficult to understand how they could have failed to attract and maintain the interest of physiologists through so many years. The facial nerve, as is well known, in its passage through the aqueduct of Fallopius receives a branch from the pneumogastric. The great Frenchman cut this branch before its junction with the facial. Immediately the ear on the corresponding side became, as he describes it, "low and hanging," while the ear of the other side remained unaffected. The animal was irritated, and the hanging ear became erect. The animal was left in repose, and the ear drooped as before. At another time he removed the superior cervical ganglion of the sympathetic.† The orbicular muscle of the eye of the same side at once became contracted, and remained so. If the globe of the eye were touched, the orbicularis contracted still more, so long as the irritation was continued; but it could not be relaxed. In another dog a section was made of the sympathetic nerve belonging to the superior cervical ganglion, so as to obtain the same persistent contraction of the orbicular muscle. A drop of ammonia was now placed on the conjunctiva, the pain causing the animal to close the eye obstinately and constantly. The peripheral fillet of the cut sympathetic was stimulated, and, in spite of the pain, the eyes were opened widely. There would thus seem to be no question that within the sheath of the pneumogastric there run fibres which terminate in the muscles of the ear, as well as that within the sheath of the superior cervical sympathetic there run fibres which terminate in the orbicular muscles of the eye. It would seem to be equally clear that the branch from the pneumogastric to the aural muscles is motor. The doubt might naturally arise as to whether it did not cause the ear to stand erect by a vaso-motor action, by constricting or enlarging the vessels, by engorging the ear with blood or depleting it. But this cannot be, because,

**Système Nerveux*, t. II., p. 40, Paris, 1858.

†*Ibid*, pp. 35, 472, 499.

in the first place, there are no appearances of anæmia or congestion about such an ear; in the second place, when the cervical sympathetic is cut, and the ear becomes plethoric, its attitude is unaltered; and, in the third place, when the cut sympathetic is irritated so as to remove the aural plethora, the aural attitude is still unaltered. As to whether the fibres from the cervical sympathetic to the orbicularis palpebrarum are motor, and not vaso-motor, is of itself perhaps not so certain. Nevertheless, the proof first adduced that a condition of extreme anæmia or extreme congestion in a muscle is not alone sufficient to produce any marked contraction or relaxation, going hand in hand with the proof that a purely motor nerve may run in a bundle of involuntary filaments, should warrant us in regarding it as very probable that the fibrils to the orbicularis are intrinsically motor.

These branches to the ear and the eyelid, however, have an action that is in a measure independent of the voluntary motor nerves of the same parts. As we have seen, when the auricular branch of the par vagum is severed, such irritation of the animal as will call forth a voluntary effort, which must pass through the facial, causes the ear to be erected. Section of the facial, on the other hand, has as a consequence a complete paralysis of the orbicularis palpebrarum, although the filament from the cervical sympathetic to this muscle is uninjured. Still again, this same section of the facial, although it be made before the junction within the aqueduct of Fallopius of the branch from the pneumogastric, leaves the ear pendant and flaccid. The involuntary and the voluntary motor nerves of the parts have each therefore, as it would seem, an action that is complementary the one to the other. Be it noted, that although the facial can erect the ear when the pneumogastric fillet has been severed, such erection remains only during the continuance of voluntary effort. Cut the facial, galvanize its peripheral end, and in spite of the cervical sympathetic not having been touched, the eyelids will be approximated. This would appear to mean that the voluntary fibre imparts to the ear and eyelid an attitude in which it is maintained by the involuntary fibre. May not the tendon-nerves, as they bear a striking air of kinship to the pneumogastric and the sympa-

thetic, play some such part in the voluntary muscles of the other parts of the body? I cannot believe that it is irrational to assume that there may be nerves in every muscle necessary to keep that muscle fixed in a certain position without an effort of volition. The countless expressions of the human face, imparted to it by muscular action, unconsciously the same through years, asleep and awake; the different conditions of contraction or relaxation of the eyelids and nostrils in different individuals; the constant station of the ears in certain quadrupeds, the peculiar positions of the different limbs, the slight flexion and pronation of the forearm, the eversion of the thigh; would all reasonably demand a set of nerve fibres that should act automatically, without continuous impulse from the will, day and night, asleep and awake, as the heart beats, as the lungs respire, and still be subject to modifications by the action of the will. Should there be such fibres, their distribution to the tendon might, as we could conceive, and as Sachs* has claimed to be so in fact, answer best the purpose of their creation; because when the tendon is set in motion the whole muscle would contract. This particular point, however, I offer as a mere surmise.

In conclusion I desire to remark that the discussion during the last few years in Germany as to the existence of inhibitory nerves has brought to the light a few phenomena that may possibly have a bearing upon the views advanced in this paper. Nothnagel* made a section of a dog's spinal cord in the dorsal region. In the course of time there ensued strongly tremulous reflex movements in the hinder extremities whenever the animal was suspended in the air by the fore paws. The sciatic nerve was then exposed. Gentle pressure upon it instantly suspended the reflex movements; strong pressure upon it greatly increased them. Tschirjew, it will be recalled, laid bare the crural nerve in a rabbit, passed a string carefully around it, raised it gently, and thereby at once abolished the tendon-reflex in the quadriceps, without apparently affecting the motility or sensibility of the knee. Exactly of

*Op. cit.

**"Beobacht. über Reflexhemmung." *Arch. f. Psych. u. Nerv.*, VI., S. 332. 1875.

what import this coincidence may be, whether Nothnagel by his gentle pressure suspended the functional activity of the same set of fibres that Tschirjew stilled by his light lifting, I am not prepared to say. I would merely have the fact borne in mind. Yet, when I recall the quick suspension of the tendon-reflex by minute causes, I am disposed to believe that the fibres in the two cases were identical; and herein may be a possible clue to the comprehension of those finely tremulous, rhythmical movements which we daily witness in paralysis agitans and disseminated sclerosis, and which serve to distinguish them so strongly from the quickly jerky movements of wider range in chorea. It is among the possibilities, too, that the symptoms of locomotor ataxia and spasmodic spinal paralysis may be better elucidated than they are at present by a further study of these nerves.

ART. VI.—CASE OF INFANTILE ENCEPHALITIS,
FOLLOWED BY ATHETOTIC SYMPTOMS.

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TOWARDS the latter end of February last a young man presented himself to me for treatment, at the North-Eastern Dispensary, who exhibited a group of symptoms which, in their aggregate, I am disposed to class under Hammond's "Athetosis." It was first noticed, on examination, that there was considerable bodily asymmetry, the entire right side of the cranium and face, as well as the right arm and right leg, being noticeably smaller than the corresponding parts upon the opposite side. This asymmetry was most marked in the face and cranium; less so in the arms, and least of all in the legs; the muscles of the atrophic side were contracted and firm, and the right side of the face was drawn, its features being sharp, contrasting in this respect with the plump left side. The next peculiarity noticed was a con-